

Lake Mead Water Quality Platforms Quality Assurance Plan with Procedures for Operating the Endeco/YSI Profiling System

**U.S. Geological Survey Water Resources Division,
Henderson, Nevada**



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1.0 Introduction

The USGS has established four near-continual, water-quality profiling stations on Lake Mead (fig. 1). Instrumentation at the USGS stations collect depth dependent, near-real-time water-quality data at programmed depth increments and time intervals. The physical and chemical parameters measured by the profiling equipment at each site include depth, temperature, pH, dissolved oxygen, specific conductance, turbidity, and fluorescence.

The objectives of the project are (1) collect continual, depth dependent measurements of selected water-quality field parameters at monitoring stations on Lake Mead, (2) assess temporal trends in water-quality field parameters measured at each monitoring site, and (3) report near real-time water-quality field-parameter data on the internet.

This quality assurance (QA) plan is based on bureau standards for continuous water quality monitoring that were published in 2001 in USGS Water Resources Investigation Report (WRIR) 00-4252, *Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation, and Reporting*. WRIR 00-4252 is available on the internet at <http://water.usgs.gov/pubs/wri/wri004252>. All personnel that work on the project must review this QA plan and WRIR 00-4252.

This QA plan presents procedures for operating the profiling equipment and servicing the water quality sensors. Section 2.0 discusses the equipment at each platform. Section 3.0 lists the standard operating procedures (SOP's) that will be followed during each service visit in an abbreviated format and in a detailed format. Section 4.0 describes additional SOP's that will be completed once each quarter. Section 5.0 describes the procedures for computing the water quality record collected at the platforms. Finally, section 6.0 contains copies of the field forms that will be filled out during site visits.

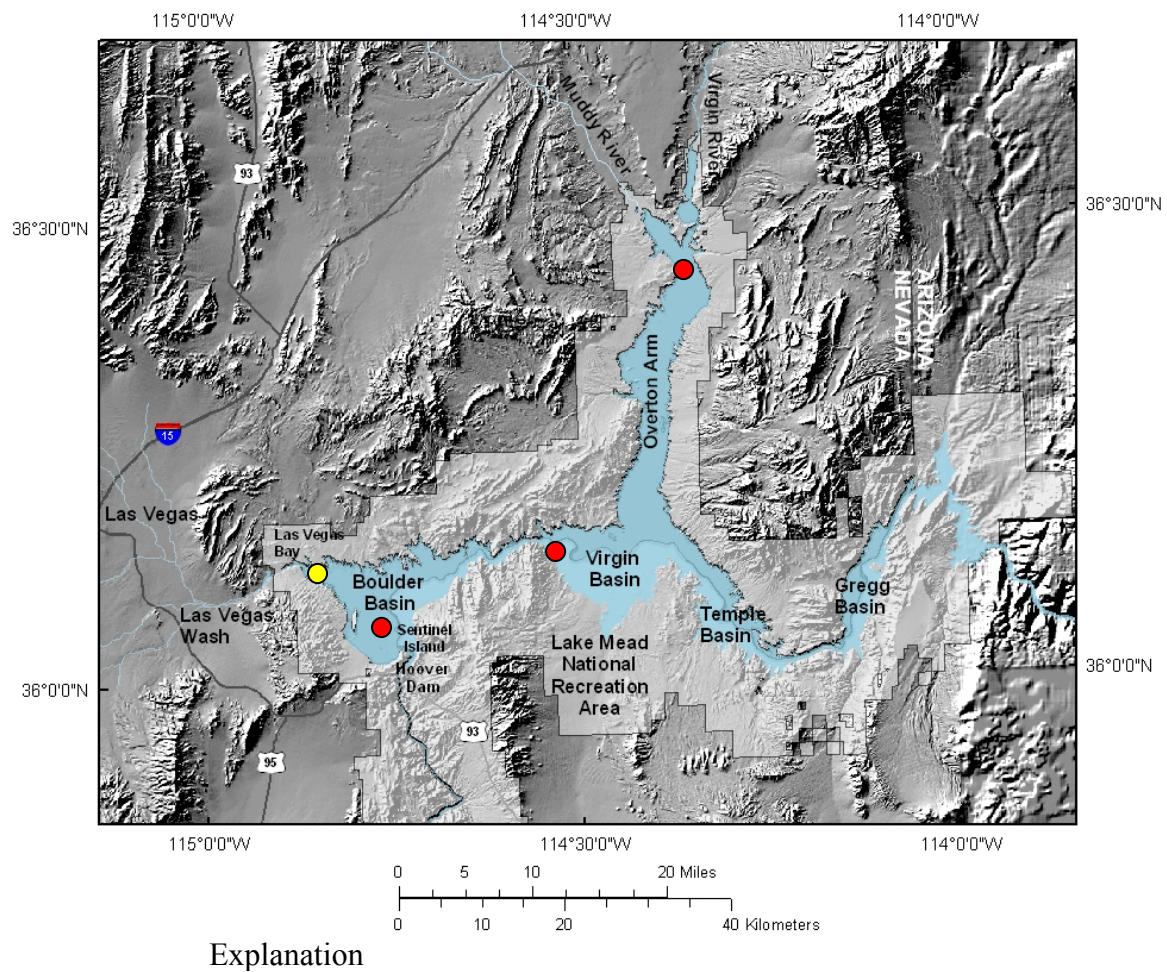


Figure 1. Locations of monitoring platforms.

2.0 Equipment at the Lake Mead Platforms

Water Quality Monitoring Equipment

Each platform is equipped with an Endeco/YSI* profiling system consisting of the following hardware (fig. 2):

- Endeco/YSI variable profiler winch assembly;
- YSI 6600 multiparameter water quality probe;
- Campbell Scientific CR10X data logger/sensor control module;
- 12 volt, 95 amp hour battery;
- Wavecom GSM cellular modem package; and a
- 30 watt solar panel for charging the battery.

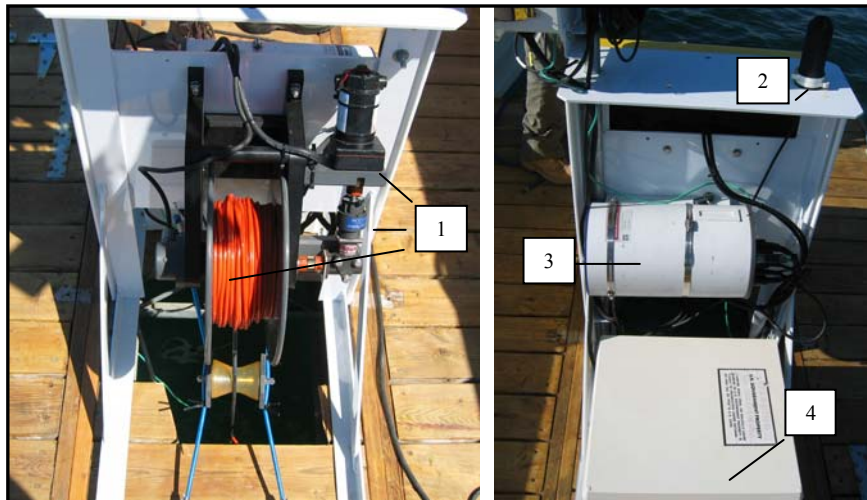


Figure 2. Photos of profiling system components (1, variable profiler winch assembly; 2, modem antenna; 3, water tight housing for CR10X and wavecom modem; and 4, water tight housing for 12 volt, 95 amp hour battery).

The YSI 6600 is equipped with the following sensors:

- depth,
- temperature,
- conductivity,
- pH,
- dissolved oxygen,
- turbidity, and
- fluorescence.

* Use of product or trade names does not constitute an endorsement.

The YSI 6600 user's manual provides information regarding communication and power options, sensor principles of operation, maintenance, and calibration. This QA plan was written with the assumption that USGS personnel working on the project are familiar with the contents of the YSI 6600 user's manual.

The variable profiler winch assembly transports the multiprobe to programmed depths. The CR10X is the microprocessor that controls the winch assembly, operates the multiprobe, stores the data collected by the multiprobe, and controls the modem that transmits the data to the base station in the USGS Henderson, NV, field office. In this QA plan, the equipment package, including the multiprobe, will be referred to as a profiling system.

Meteorological Monitoring Equipment

Three of the four monitoring stations (fig. 1) also are equipped with the following meteorological instruments:

- RM Young 05106-5 wind speed and direction anemometer,
- Li-COR LI200X Pyranometer (solar radiation sensor),
- Vaisala PTB101B barometer, and
- Vaisala HMP45C-L air temperature/relative humidity sensor.

The meteorological instruments are controlled by the same CR10X that controls the profiling system. Meteorological data stored by the CR10X are hourly averages of readings taken every 10 seconds. This QA plan does not address the meteorological data collection at the platforms.

3.0 Standard Operating Procedures for Service Visits

The standard operating procedures that will be followed during each service visit are summarized below. Detailed information regarding each step is given at the end of the list. Note that used calibration solutions and rinse water will be poured into a waste container and not into the lake.

- 1) Inspect the platform for damage or items in need of repair. Record observations on the site visit sheet under the remarks section (attachment 1).
- 2) Bring the multiprobe to the surface.
- 3) Inspect the multiprobe and cable connection.
- 4) Immerse the multiprobe in a bucket of lake water that is maintained at surface water temperature. Record the pre-cleaned sensor readings in the bucket of lake water on the site visit sheet.
- 5) Determine the amount of fouling and electronic drift associated with the DO sensor using the saturated air in water method; record the data on the calibration/check sheet (attachment 2).
- 6) Clean the sensors.

- 7) Remove the DO sensor and replace it with a fresh sensor that was serviced at least 24 hours prior to the site visit. Calibrate the DO sensor using the saturated air in water method; record the calibration data on the calibration/check sheet.
- 8) Immerse the multiprobe in the bucket of lake water maintained at surface water temperature and record the cleaned sensor readings on the site visit sheet.
- 9) Check the calibration of the sensors. Calibrate the sensors if they exceed the calibration criteria; record data on the calibration/check sheet.
- 10) Collect and filter a grab sample of lake water for laboratory chlorophyll analysis. Verify fluorescence sensor response with the grab sample, a 50 percent dilution of the grab sample, and blank water. Record the data on the chlorophyll sample sheet (attachment 3). Store the samples on ice.
- 11) Record post service sensor readings in the bucket of lake water maintained at surface water temperature on the site visit sheet.
- 12) Reconnect the multiprobe to the profiling system and deploy.

Step 1: Platform Inspection

Upon arrival at the site, a basic inspection of the platform shall be completed. The condition of the solar panel, anchor chain attachment points, platform surface, and weather box shall be noted on a site visit sheet (attachment 1). If there are items that need repair and cannot be repaired during the service visit, they need to be brought to the attention of the project chief as soon as possible. Equipment on the platform that is not maintained could be dangerous to you and may damage the profiling system.

Step 2: Establish Communications and Bring the Profiler to the Surface

After the inspection, establish communications with the profiling system using the Loggernet program. Record two sets of sensor readings on the site visit sheet before bringing the multiprobe to the surface. These data will typically be from the units parking depth and will not be used for records computation; nonetheless, they are a useful indicator of the condition of the sensors. Bring the multiprobe to the surface by using the magnetic switch on top of the water tight container that houses the CR10X and modem. When the multiprobe has surfaced, terminate communications within the Loggernet program and disconnect the power cable from the profiling system.

Step 3: Multiprobe and Communication Cable Inspection

Visually inspect the cable connection on top of the multiprobe for signs of corrosion; i.e., green precipitates around the connections. If green corrosion precipitates are present on the cable connection, the cable must be disconnected and the connection cleaned. Clean the cable connection by spraying the conductors with a contact cleaner and gently swabbing the conductor surfaces with a q-tip. Dry the conductors with canned air.

Remove and visually inspect the o-ring inside the cable connection on top of the multiprobe. Replace the o-ring if you see or suspect damage. Apply a thin coat of silicone grease to the o-ring before returning it to the multiprobe cable connection.

Step 4: Pre Cleaned Sensor Readings

The data collected during steps 4-8 are used to determine the amount of sensor fouling. Fouling is the difference between the pre-cleaned sensor readings in an environmental sample and the cleaned sensor readings in the same environmental sample. It is critical that these steps are completed with care so that accurate fouling corrections can be applied to data that are logged by the profiling system between service visits.

Fill a 5 gallon bucket with water from the lake and secure it to the side of the platform so that most of the bucket is immersed in the lake. This will help maintain the contents of the bucket at surface water temperature. Disconnect the winch cable from the multiprobe and connect the YSI 650 communications cable to the multiprobe. Next, gently immerse the multiprobe (sensors down) in the 5 gallon bucket of lake water. Establish communications with the multiprobe via the YSI 650 hand held device. Allow the sensor readings to stabilize according to the criteria in table 1. This could take several minutes because the multiprobe must thermally equilibrate with the water in the bucket. Once the sensor readings have stabilized, record two to three sets values from each sensor on the site visit sheet. These data are the pre-cleaned sensor readings.

Table 1. Stabilization criteria for recording field measurements.

| Sensor | Stabilization criteria for measurements (variability should be within the value shown) |
|---|---|
| Temperature | $\pm 0.2^{\circ} \text{C}$ |
| Specific Conductivity: when $\leq 100 \mu\text{S/cm}$ when $> 100 \mu\text{S/cm}$ | ± 5 percent ± 3 percent |
| pH | ± 0.1 unit |
| Dissolved Oxygen | $\pm 0.3 \text{ mg/L}$ |
| Turbidity | ± 10 percent |
| Fluorescence | ± 1 percent |

Step 5: Dissolved Oxygen Combined Fouling and Drift Check

Because the DO sensor cannot be cleaned without replacing the teflon membrane, a calibration check is used to determine a combined fouling and electronic drift correction. Remove the multiprobe from the bucket of lake water and unscrew the sensor guard. Add about 50 milliliters (ml) of deionized water to the calibration cup. With the multiprobe (and sensors) pointing down, install the calibration cup on the multiprobe by engaging only two or three threads so that the air inside the calibration cup is connected to the atmosphere (it is important that the air inside the calibration cup is connected to the atmosphere so that atmospheric pressure is maintained inside the cup). Place the multiprobe, with the sensors pointing down, into a bucket partially filled with lake water. The water level in the bucket should not be above the top of the calibration cup where it is threaded onto the multiprobe. Immerse this bucket in the lake and secure it to the platform similar to the bucket used for the pre cleaned sensor readings. Allow the sensors, air, and water inside the calibration cup adequate time to thermally equilibrate with the water in the bucket. This will take at least 10 minutes. Do not rush this process.

Once the DO readings stabilize, record two to three values, including DO in mg/L and DO sensor charge, on the field calibration/check sheet (DO sensor charge values help identify DO sensors that are near the end of their operational lifespan). In the space provided on the calibration/check sheet, record the theoretical DO concentration at the temperature and pressure inside the calibration cup (the pressure in the cup should be at atmospheric pressure). The difference between the theoretical value and the DO sensor reading in mg/L is due to fouling and electronic drift. After this step is completed, power down the multiprobe.

Step 6: Cleaning the Sensors

Remove the calibration cup and carefully clean the sensor bodies with a soft bristle tooth brush and a mild detergent, such as a dilute (0.2 percent by volume) liquinox solution. Use the small brush provided by YSI to clean the electrodes of the conductivity sensor. Use a q-tip saturated with isopropyl alcohol to clean the surface of the glass bulb on the pH electrode and the lenses of the turbidity and chlorophyll sensors. Inspect the wipers on the turbidity and chlorophyll sensors and replace as needed (be certain to use an orange wiper on the chlorophyll sensor and a gray wiper on the turbidity sensor). Inspect the pressure sensor opening, which is a small hole on the side of the multiprobe, just above the sensors.

Step 7: Exchanging and Calibrating the Dissolved Oxygen Sensor

The DO sensor is changed out every site visit. The replacement sensor must be prepared at least 24 hours prior to the field trip. Place the multiprobe in a stand with the sensors in the upright position and dry around the base of each sensor with a paper towel and canned air. Remove the DO sensor. Dry the conductor surfaces in the DO slot of the multiprobe with canned air. Apply a thin coat of silicone grease to the o-rings on the base of the replacement DO sensor and install the sensor. Calibrate the sensor using the saturated air in water method (see step 9). Record the serial number of the replacement DO sensor and the sensor that was removed from the multiprobe on the calibration/check sheet.

Step 8: Cleaned Sensor Readings

The environmental readings after the sensors have been cleaned (or replaced, in the case of the DO sensor) can now be obtained. Replace the calibration cup with the sensor guard and rinse the multiprobe with lake water. Place the multiprobe in the bucket of lake water and establish communications. Allow time for the sensors to thermally equilibrate (this takes up to 10 minutes, be patient). After the readings have stabilized, record two sets of readings on the site visit sheet.

Step 9: Calibration Check and Calibration

Electronic drift is the difference between the cleaned sensor reading in a standard and the standard value. Drift is determined for each sensor via a calibration check after the sensors have been cleaned and rinsed. A sensor must be calibrated (or replaced, if it is the temperature sensor) if its output value in a standard exceed the calibration criteria shown in table 2. The calibration criteria for temperature, specific conductance, dissolved oxygen, pH, and turbidity are from WRIR 00-4252. The calibration criteria for fluorescence and depth are specific to this project.

Table 2. Calibration criteria for continuous water quality monitors.

| | |
|----------------------|---|
| Temperature | $\pm 0.2\text{ }^{\circ}\text{C}$ |
| Specific conductance | The greater of $\pm 5\text{ }\mu\text{S/cm}$ or ± 3 percent of the measured value |
| Dissolved oxygen | $\pm 0.3\text{ mg/L}$ |
| pH | $\pm 0.2\text{ pH unit}$ |
| Turbidity | The greater of $\pm 2\text{ NTU}$ or ± 5 percent of the measured value |
| fluorescence | ± 5 percent fluorescence |
| Depth | $\pm 0.3\text{ m}$ |

The procedures for checking the calibration of each sensor are given below.

Depth

The YSI 6600 multiprobe is equipped with a non-vented, deep-level pressure sensor. The operational range of the sensor is 0 to 200 meters (m) with an accuracy of ± 0.3 m throughout the range of the sensor (table 3).

Table 3. Pressure sensor specifications for YSI 6600 multiprobe.

| | |
|------------------------------|--------------------------------|
| Sensor Type | Stainless steel strain gage |
| Range | 0 – 200 meters |
| Accuracy | ± 0.3 meters |
| Resolution | 0.001 meters |
| Project calibration criteria | Mean value of ± 0.3 meters |

Pressure sensors usually require little maintenance and are generally accurate. The following procedure should be adequate to check and maintain the calibration of the sensor. Once a month, the multiprobe will be attached to a 30 m communication cable that is marked at 5 m intervals in a manner that 0 m is at the opening for the depth sensor on the multiprobe. Using the depth marks on the communications cable, the YSI 6600 will be lowered to 5, 15, and 30 m below the lake's surface. The sensor readings at each depth will be recorded on the calibration check sheet (attachment 2). A weight will be added to the multiprobe to ensure that the cable is vertical during the calibration check. If any of the sensor readings exceed ± 0.3 m of the specified depth, the sensor must be calibrated.

The depth sensor accepts only a one point calibration at zero depth. This is done by zeroing the sensor at atmospheric pressure. Refer to the YSI user's manual for instruction on how to zero the sensor. After the sensor is calibrated, repeat the calibration check. If the sensor values continue to fall outside the calibration criteria, a calibration curve will have to be developed.

Temperature

The temperature sensor on the YSI 6600 utilizes a thermistor of sintered metallic oxide that changes predictably in resistance with temperature variation. The range of the sensor is -5 to 45 °C and is accurate to within ± 0.15 °C (Table 4).

Table 4. Temperature sensor specifications for YSI 6600 multiprobe.

| | |
|------------------------------|--|
| Sensor Type | Thermistor |
| Range | -5 to 45 °C |
| Accuracy | ± 0.15 °C |
| Resolution | 0.01 °C |
| Depth | 200 m |
| Project replacement criteria | ± 0.2 °C of calibrated field thermometer value |

The temperature sensor is the most important sensor on the multiprobe. Temperature is a fundamental property of any medium. The output values of the DO, specific conductance, and pH sensors depend on a properly functioning temperature sensor. For this reason, the response of the temperature sensor must be checked each service visit. Temperature sensor readings will be compared to a calibrated thermometer (calibrated against an ASTM thermometer). To check the sensor, the YSI will be inverted so that the sensors are in the upright position. The calibration cup will be filled with water. The calibrated thermometer will be placed in the calibration cup along side the temperature sensor. The sensor and thermometer must be allowed to thermally equilibrate with the water, wait at least 15 minutes. After the equilibration time has elapsed, record at least three simultaneous temperature readings from the YSI and the calibrated thermometer on the calibration check sheet. If the temperature sensor reading is greater than ± 0.2 °C of the calibrated thermometer, the sensor fails the calibration check and must be replaced (temperature sensors cannot be calibrated).

Specific Conductance

The YSI 6600 utilizes a cell with four pure nickel electrodes for the measurement of solution conductance. Two of the electrodes are current driven and two are used to measure the voltage drop. The measured voltage drop is then converted into a conductance value in milli-Siemens (mS), which is equivalent to millimhos. This value is multiplied by the cell constant, which is approximately 5.0 cm^{-1} for the YSI 6600, to give conductance in units mS/cm. Conductivity values are highly dependent on temperature, varying as much as 3 percent per 1 °C. For this reason, the YSI 6600's used for this project are set to record specific conductance, which uses the raw conductance value and the temperature at the time of measurement to produce a specific conductance value compensated to 25 °C (note that the values for specific conductance are only as good as the temperature sensor values).

The range of the sensor is 0 to 100,000 $\mu\text{S/cm}$ (note that YSI 6600's for this project are set to report $\mu\text{S/cm}$) and is accurate to within ± 0.5 percent + 1 $\mu\text{S/cm}$ (table 5). The calibration criteria for the sensor are the greater of ± 5 $\mu\text{S/cm}$ or ± 3 percent of the measured value. For example, for a standard of 100 $\mu\text{S/cm}$, the criteria is plus or minus 5 $\mu\text{S/cm}$ because this value is greater than 3 percent of the measured value; i.e., 3 $\mu\text{S/cm}$.

In a standard of 1,000 $\mu\text{S}/\text{cm}$, the calibration criteria is ± 3 percent of the measured value; i.e., 30 $\mu\text{S}/\text{cm}$, because this value is greater than 5 $\mu\text{S}/\text{cm}$.

Table 5. Conductivity sensor specifications for YSI 6600 multiprobe.

| | |
|------------------------------|---|
| Sensor type | 4 electrode cell with autoranging |
| Range | 0 to 100,000 $\mu\text{S}/\text{cm}$ |
| Accuracy | $\pm 0.5\%$ of reading + 1 $\mu\text{S}/\text{cm}$ |
| Project Calibration criteria | The greater of $\pm 5 \mu\text{S}/\text{cm}$ or ± 3 percent of the measured value |

The calibration of the conductivity sensor will be checked with three standards with the following values; 740, 1,000, and 2,500 $\mu\text{S}/\text{cm}$. The temperature of the standards must be at or near the temperature of the surface of the lake when the calibration check is completed. This can be achieved by immersing the standards in the lake for about 30 minutes. Make sure the caps on the standard bottles are tightly secured before immersing the standards in the lake.

If the calibration criteria are exceeded in any standard, the sensor must be calibrated. The YSI 6600 conductivity sensor accepts only a one-point calibration. The standard used for the one point calibration will be 1,000 $\mu\text{S}/\text{cm}$ (this value is closest to those measured in the lake). After the sensor is calibrated, the calibration should be checked with 740 and 2,500 $\mu\text{S}/\text{cm}$ standards. The calibration data will be entered in to the multiprobe calibration/check sheet.

pH

The YSI 6600 uses a field replaceable pH electrode for determination of hydrogen ion activity, which is reported in pH units. The probe is a combination electrode consisting of a proton selective glass reservoir filled with buffer at pH 7 and a Ag/AgCl reference electrode immersed in a gel electrolyte solution. Protons on both sides of the glass (media and buffer solution) selectively interact with the glass, setting up a potential gradient across the glass membrane. Since the hydrogen ion concentration in the internal buffer solution is invariant, this potential difference, determined relative to the Ag/AgCl reference electrode, is proportional to the pH of the media.

The pH sensor is accurate to ± 0.2 pH units and has a range of 0 to 14 pH units (table 6).

Table 6. pH sensor specifications for the YSI 6600 multiprobe.

| | |
|------------------------------|-----------------------------|
| Sensor Type | Glass combination electrode |
| Range | 0 to 14 units |
| Accuracy | ± 0.2 units |
| Resolution | 0.01 units |
| Depth | 200 meters |
| Project calibration criteria | ± 0.2 unit |

The calibration of the pH sensor is checked with 7 and 10 standard solutions. The temperature of the standards should be as close to field conditions as possible. This can be achieved by immersing the standards in lake water immediately upon arrival at the platform (be sure that the bottle caps are tight before immersing the standards in the lake). If the sensor readings in one or both standards exceed the calibration criteria, the sensor must be calibrated. A two-point calibration is necessary. Use standards that bracket the values expected in the profile; i.e., pH 7 and pH 10 standards. Once the calibration is complete, the linear response of the sensor should be checked with a pH 4 standard.

The millivolt response of the sensor needs to be recorded in addition to the pH value. This will help identify pH sensors that are near the end of their operational lifetime. The pH calibration data will be entered into the multiprobe calibration/check sheet.

Dissolved Oxygen

The DO sensor is a rapid-pulse, Clark type polarographic design. It has a range of 0 to 50 mg/L and an accuracy of ± 2 percent of the reading (about 0.2 mg/L) in the 0 to 20 mg/L range and ± 6 percent in the 20 to 50 mg/L range (table 7). The sensor employs a digital technology that eliminates the need for stirring the medium during the measurement. The sensor works as follows: dissolved oxygen gas diffuses across the teflon membrane and is reduced to hydroxide anion at the gold cathode; the corresponding half cell reaction is oxidation of silver at the silver anode. The sensor measures the charge (current divided by time) associated with the reduction of oxygen at the gold cathode. This charge is directly proportional to the partial pressure of dissolved oxygen in the medium.

Table 7. Dissolved oxygen sensor specifications for the YSI 6600 multiprobe.

| | |
|------------------------------|---|
| Sensor Type | Rapid Pulse-Clark type, polarographic |
| Range | 0 to 50 mg/L |
| Accuracy | 0 to 20 mg/L; ± 2 percent of the reading or 0.2 mg/L, whichever is greater. 20 to 50 mg/L; ± 6 percent. |
| Resolution | 0.01 mg/L |
| Depth | 200 meters |
| Project calibration criteria | ± 0.3 mg/L |

Check the dissolved oxygen calibration with the saturated air in water method. Add about 50 milliliters (ml) of deionized water to the calibration cup. With the multiprobe (and sensors) pointing down, install the calibration cup on the multiprobe by engaging only two or three threads so that the air inside the calibration cup is connected to the atmosphere (it is important that the air inside the calibration cup is connected to the atmosphere so that atmospheric pressure is maintained inside the cup). Place the multiprobe, with the sensors pointing down, into a bucket partially filled with lake water. The water level in the bucket should not be above the top of the calibration cup where it is threaded onto the multiprobe. Immerse this bucket in the lake and secure it to the platform. Allow the sensors, air, and water inside the calibration cup adequate time to thermally equilibrate with the water in the bucket. This will take at least 10 minutes. Do not rush this process. Once the DO readings stabilize, record two to three values on the multiprobe calibration/check sheet. Also record the DO sensor charge. If the charge of the DO sensor does not fall between 25-100, it should be replaced. In the space provided on the multiprobe calibration/check sheet, record the theoretical DO concentration at the temperature and pressure inside the calibration cup (the pressure in the cup should be at atmospheric pressure). If the sensor reading exceeds the theoretical dissolved oxygen concentration by ± 0.3 mg/L, the sensor must be calibrated.

Calibrate the sensor using the saturated air in water method. Configuring the YSI 6600 for the DO calibration check is the first step for this calibration procedure. The next step is to enter the current barometric pressure into the YSI 6600. This calibration method depends on accurate absolute barometric pressure values in millimeters of mercury (mmHg), and relatively steady temperature values. Refer to the YSI 6600 user's manual for more instruction on how to complete the calibration.

A salinity correction is not required for DO data collected at Lake Mead. In general, waters with specific conductance values less than 8,000 $\mu\text{S}/\text{cm}$ have salinity correction factors that are less than the accuracy of the DO sensor.

Turbidity

Turbidity is a measure of the “cloudiness” of a water sample. The turbidity sensor equipped with the YSI 6600 emits light near the infrared region of the spectrum (830-890 nm) with a light emitting diode (LED). The amount of this light scattered by particles in the water sample at an angle normal to the light source is detected by a high sensitivity photodiode. The output values of the turbidity sensor are in nephelometric turbidity units (NTUs). The range of the turbidity sensor is 0-1,000 NTUs (table 8).

Table 8. Turbidity sensor specifications for the YSI 6600 multiprobe.

| | |
|------------------------------|---|
| Sensor type | Optical, 90° scatter, with mechanical cleaning |
| Range | 0 to 1,000 NTU |
| Accuracy | The greater of ± 2 NTU or ± 5 percent of the measured value |
| Resolution | 0.1 NTU |
| Depth | 200 meters |
| Project calibration criteria | The greater of ± 2 NTU or ± 5 percent of the measured value |

The calibration of the turbidity sensor is checked with 0, 20, and 50 NTU secondary standards. The 20 and 50 NTU secondary standards are dilutions of a 4,000 NTU stock formazine solution. The zero standard is filtered, deionized water. The field standards are checked with a lab turbidity meter that is calibrated with primary standards on a monthly basis and secondary standards prior to each use.

If the calibration criteria are exceeded with any one standard, the sensor must be calibrated. A two point calibration is necessary. The first point of the calibration must be completed with a 0 NTU standard. The second point is 50 NTU. The linearity of the calibration is checked with a standard of intermediate value; i.e., 20 NTU. Refer to the YSI 6600 user’s manual for more information regarding turbidity sensor calibration. The calibration check and, if necessary, the calibration data will be recorded on the calibration/check sheet.

Fluorescence

The operating principal of the sensor utilizes the fact that chlorophyll will fluoresce when it is irradiated with ultraviolet (uv) light. The sensor emits uv energy with a peak wavelength of approximately 470 nanometers (nm). In response, chlorophyll present in the irradiated water sample emits light in the 650-700 nm range of the energy spectrum. A photo detector in the sensor measures the intensity of this light. The sensor is equipped with an optical filter that prevents energy outside the 650-700 nm range from reaching the photo detector. In general, the intensity of the light emitted by chlorophyll in the sample is proportional to the amount of chlorophyll in the sample; however, the insitu

method of measuring chlorophyll is subject to numerous errors. YSI explains these sources of error, which are summarized below.

- Differing species of algae with differing shape and size will likely fluoresce differently even if the type and concentration of chlorophyll are identical (this significantly limits the accuracy of insitu measurements).
- Phytoplankton fluorescence increases as temperature decreases and each species of phytoplankton is likely to have slightly different temperature dependence.
- Empirical data indicate that, at constant phytoplankton level, the fluorescent signal can change significantly on a diurnal schedule, showing less fluorescence when oxygen is being produced and more fluorescence during the resting phase of the organisms. This effect would produce errors in the absolute values of chlorophyll.
- While it is probable that most of the fluorescence is due to suspended plant and algal matter and that much of the fluorescence from this biomass is due to chlorophyll, it is impossible to exclude interferences from other fluorescent species using this approach.

YSI does not provide accuracy specifications for the fluorescence sensor (table 9). This is due in part to sources of error listed above and because universal chlorophyll calibration standards do not exist.

Table 9. Fluorescence sensor specifications for the YSI 6600 multiprobe.

| | |
|------------------------------|--|
| Sensor type | Optical, fluorescence, with mechanical mixing |
| Range | 0 to 400 µg/L; 0-100 percent full scale fluorescence units |
| Accuracy | No specifications provided |
| Resolution | 0.1 µg/L; 0.1 % FS |
| Depth | 200 meters |
| Project calibration criteria | ± 1 percent fluorescence in deionized water |

Due to the numerous sources of variability, it is not scientifically defensible to report chlorophyll concentrations using the default relationship between fluorescence and chlorophyll programmed in the YSI 6600. A practical alternative to reporting chlorophyll in µg/L is to take advantage of the ability of the sensor to output percent fluorescence (%FS). In this mode, the sensor will report only relative values of fluorescence in the sample being measured. %FS can then be converted to chlorophyll concentration using a post calibration procedure.

This procedure requires that one sample is collected from the lake surface at each site during service visits. This sample will be mixed in a churn splitter and a 500-1,000 milliliter aliquot will be filtered. The filter will be sent to the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colorado, and analyzed for chlorophyll-a (NWQL lab cod 586) and chlorophyll-b (NWQL lab code 587). The %FS of an unfiltered aliquot from the churn splitter will be measured by the fluorescence sensor on the dedicated multiprobe. The relationship between total chlorophyll (chlorophyll a + b) and %FS will be quantified by plotting the lab measured values for chlorophyll and the field measurements of %FS in the water filtered for the lab samples.

The response of the sensor will be verified in the field by measuring the %FS of an undiluted water sample, a 50 percent dilution of the water sample, and a blank water sample. Field procedures for collecting the chlorophyll sample and checking the response of the fluorescence sensor are given below.

Step 10: Collect Chlorophyll Sample and Check Fluorescence Sensor Response

Record data from this procedure on the chlorophyll sample sheet (attachment 3).

- 1) Fill a churn splitter with water from the surface of the lake and churn to thoroughly mix the suspended matter in the water (continue to churn the sample while filling sample containers as described in the steps below);
- 2) fill a 500 ml volumetric flask with water from the churn;
- 3) filter the contents of the flask through a 47 mm glass fiber filter;
- 4) place the filter in a glass vial or petri dish, cap, wrap in aluminum foil, and store on ice (ship sample on dry ice immediately upon return to the office);
- 5) rinse the multiprobe sensors and calibration cup three times with water from the churn;
- 6) measure the %FS of at least 250 ml of water from the churn with the multiprobe (this value will be compared to the lab results and also will be the first point used to check the sensor response);
- 7) Fill the volumetric flask with 500 ml of water from the churn (be sure to mix the contents of the churn) and transfer the water to a clean, 1 liter poly bottle;
- 8) rinse the volumetric flask three times with filtered deionized water.
- 9) fill the volumetric flask with filtered, deionized water and transfer the water to the 1 liter poly bottle;
- 10) gently mix the contents of the 1 liter bottle and measure the %FS of a 250 ml aliquot with the multiprobe (this is the 50 percent dilution reading, it is the second point used to check the sensor response and should be about one half the %FS value measured in the undiluted grab sample in step 6);
- 11) rinse the multiprobe sensors and calibration cup three times with filtered, deionized water;
- 12) measure the %FS of 250 ml of filtered deionized water (this is the third point used to check the sensor response and should be at or near zero).

If the %FS reading in deionized water is outside the range of ± 1 %FS, the sensor needs to be zeroed. This is a simple procedure. Refer to the YSI 6600 user's manual for detailed instructions for zeroing the sensor.

Step 11: Record post service sensor readings

At this point, the sensors have been cleaned and, if needed, calibrated. Next, replace the calibration cup with the sensor guard and thoroughly rinse the multiprobe with lake water. Immerse the multiprobe in the bucket of Lake Mead water and record a final set of environmental values on the site visit sheet before redeploying the multiprobe. Before recording any values, gently mix lake water in the bucket to suspend organic matter and other debris that has settled on the bottom of the bucket.

Step 12: Deploy Profiling System

The final step during the service visit is to deploy the multiprobe. Power down the 650 communications device and disconnect the YSI 6600 from the communications cable. Connect the YSI 6600 to the winch cable. Power up the lap top computer and start the Loggernet program. Reconnect the power cable to the CR10X/modem housing. Within the Loggernet program, connect to the CR10X and verify that the YSI 6600 is communicating to the CR10X. Use the magnetic switch to lower the multiprobe to its parking depth. At this point, it is safe to disconnect from the CR10X from within the Loggernet program. Close Loggernet, power down the lap top, and disconnect the lap top communications cable from the CR10X/modem housing. The CR10X will revert to autonomous mode 20 minutes after the power cable was reconnected.

4.0 Additional Standard Operating Procedures

The SOP's established in section 3.0 will ensure that high quality data are collected at each water quality platform; however, there are two additional QA procedures that will be implemented; the first procedure will verify the overall quality of the water quality data collected during a profile, and the second procedure will verify the quality of the chlorophyll data reported by the NWQL. Both of these QA steps will be completed once each quarter.

Profile Comparisons

Once each quarter, simultaneous profiles will be completed at each platform with two multiprobes. One of the multiprobes will be the YSI 6600 dedicated to the platform of interest, and the second multiprobe will be any carefully serviced and calibrated unit capable of measuring temperature, depth, specific conductance, pH, dissolved oxygen, turbidity, and %FS. The actual depth of the profilers in the water column shall be determined from the communications cables, which should be marked at identical depth intervals, attached to the multiprobes. The purpose of this QA procedure is to verify water quality trends in the profile, such as the depth of the epilimnion, metalimnion, and hypolimnion. Data collected during the simultaneous profiles will be recorded on the quarterly profile comparison sheet (attachment 4). The data collected during this QA procedure will not be used to compute the water quality record at the platforms.

Duplicate Chlorophyll Sample Collection and Analysis

Once each quarter, the grab sample collected during a routine service visit will be split into two; an original grab sample and a duplicate grab sample. The original and duplicate grab samples will be submitted to the USGS NWQL water quality lab. The purpose of the duplicate grab sample is to verify the chlorophyll values measured by the NWQL.

5.0 Records Computation

Water quality data files logged by the profiling system at each site are transmitted daily to a base station computer at the Henderson field office. These data are checked for viruses and run through several scripts that perform various data file formatting operations. The data are then entered into the USGS NWIS database via ADAPS (Automated Data-Processing System) and posted on the project website, which can be accessed at <http://nevada.ugsg.gov/lmqw>. The entire process is automated. This ensures that near real time data are consistently available on the web and frees up project personnel for additional data processing procedures and preparation of the yearly data review package. Data processing and preparation of the data review package are the two components of records computation.

Data Processing

Data processing consists of 1) initial data evaluation, 2) application of corrections and shifts, and 3) final data evaluation.

Initial Data Evaluation

Initial data evaluation will be completed daily by the project chief or his/her designee. The daily data transmissions from the sites will be checked for completeness and for obvious inaccuracies, such as spikes in the chlorophyll data that may result from a malfunctioning wiper on the sensor. Up to date plots of the raw data will be maintained and used to help identify spurious data and event related changes in the water quality data. An event related change in water quality in Las Vegas Bay could result from a high flow event in Las Vegas Wash. Every attempt should be made to identify causes for changes in water quality data collected at the platforms.

Application of Corrections and Shifts

The fouling and drift corrections will be applied to the data within one week of the service visit by the project chief. Criteria for water quality data corrections and shifts are similar to the calibration criteria. Data corrections and shifts will be applied when the fouling and/or drift checks show the sensor readings exceed the criteria shown in table 10.

Table 10. Criteria for water quality data corrections and shifts.

| | |
|----------------------|---|
| Temperature | $> \pm 0.2\text{ }^{\circ}\text{C}$ |
| Specific conductance | The greater of $\pm 5\text{ }\mu\text{S/cm}$ or ± 3 percent of the measured value |
| Dissolved oxygen | $> \pm 0.3\text{ mg/L}$ |
| pH | $> \pm 0.2\text{ pH unit}$ |
| Turbidity | The greater of $\pm 2\text{ NTU}$ or ± 5 percent of the measured value |
| fluorescence | ± 2 percent fluorescence in zero fluorescence solution |
| Depth | $> \pm 0.3\text{ m}$ |

Fouling Corrections

As stated in section 3.0, fouling is the difference between the sensor measurements in the same environmental sample before and after the sensors are cleaned (see section 3.0, steps 4-8). Fouling corrections are applicable to specific conductance, DO, pH, turbidity, and %FS data. Fouling corrections are applied as datum corrections in ADAPS. This assumes that the source of fouling; i.e., algae growth on a sensor or poisoning of a sensor anode, occurs at a steady rate between sensor inspections. A datum correction in ADAPS is applied as a linear interpolation over the time between sensor inspections. Please refer to WRIR 00-4252 for more information regarding the application of fouling corrections.

Drift Corrections

Electronic drift is the difference between the cleaned sensor reading in a calibration standard and the calibration standard value (see section 3.0, step 9). Drift is assumed to occur at a constant rate between service intervals; therefore, a drift correction is applied as a linear interpolation over the time between calibrations. Drift corrections are applicable to specific conductance, DO, pH, depth, and turbidity data. Drift corrections are not applied to %FS data because universal standards for this parameter do not exist.

In ADAPS, drift corrections are applied as three-point variable shifts. Three point variable shifts are the preferred method for application of drift corrections because this method accounts for varying sensor response to calibration standards of different values. There are two kinds of three point variable shifts, percentage shifts and V-shifts. A percentage shift is used when the response of a sensor in three calibration standards of differing values is linear, where linearity is defined as a best fit line to the sensor and calibration standard data with an R^2 value of 0.90 or greater. A V-shift is used when the sensor response of a given sensor to three calibration standards is not linear. Each point in a V-shift is simply the difference between the sensor reading and calibration standard value. Please refer to WRIR 00-4252 for more information regarding the application of drift corrections.

Maximum Allowable Limits for Applying Data Corrections and Variable Shifts

Datum corrections and variable shifts are excellent tools for managing data that are logged on a continuous or near continuous basis; however, there is a point when sensors are so badly fouled or out of calibration that application of a correction and/or shift to the data logged since the last service interval does not improve the record. Maximum allowable limits are often established to define when data are too poor to correct or publish. This project will use the maximum allowable limits published in WRIR 00-4252 and a project specific limit for depth (table 11).

Table 11. Maximum allowable limits for applying corrections and publishing water quality data.

| | |
|----------------------|---------------------------------------|
| Temperature | ± 2.0 °C |
| Specific conductance | ± 30 percent |
| Dissolved oxygen | The greater of 2.0 mg/l or 20 percent |
| pH | ± 2 pH units |
| Turbidity | ± 30 percent |
| Fluorescence | Not applicable |
| Depth | ± 1.0 m |

If the fouling check or calibration check show that the sensor readings fall outside the maximum allowable limits shown in table 10, corrections will not be applied to the data logged since the last service visit. The record logged since the last service visit will be carefully examined to determine when the sensor(s) of interest failed. Data collected after the sensor failed should not be entered into NWIS. Data logged prior to the sensor failure should be entered into NWIS; however, corrections will not be applied to this data. These data will be rated as poor (see the next section). Data that are not entered into NWIS will be stored in a project database.

Final Data Evaluation

Final data evaluation consists of reviewing the data record, checking shifts, and making any needed final corrections. When completed, the data are verified for publication by ensuring they fall within maximum allowable limits (table 10) and then rated for quality. Temperature, specific conductance, DO, pH, and turbidity data are rated as excellent, good, fair, or poor according to the criteria given in WRIR 00-4252, which are shown in table 12. Project specific criteria for depth data are also shown in Table 11. The accuracy rating is based on data values recorded before any shifts or corrections are applied.

Table 12. Criteria for rating near continuous water quality data.

| Measured physical property | Excellent | Good | Fair | Poor |
|----------------------------|-----------------|--------------------|--------------------|--------------|
| Temperature (°C) | $\leq \pm 0.2$ | $> \pm 0.2$ to 0.5 | $> \pm 0.5$ to 0.8 | $> \pm 0.8$ |
| Specific conductance (%) | $\leq \pm 3$ | $> \pm 3$ to 10% | $> \pm 10$ to 15% | $> \pm 10$ |
| DO (mg/l) | $\leq \pm 0.3$ | $> \pm 0.3$ to 0.5 | $> \pm 0.5$ to 0.8 | $> \pm 0.8$ |
| pH (units) | $\leq \pm 0.2$ | $> \pm 0.2$ to 0.5 | $> \pm 0.5$ to 0.8 | $> \pm 0.8$ |
| Turbidity (%) | $\leq \pm 5\%$ | $> \pm 5$ to 10% | $> \pm 10\%$ to 15 | $> \pm 15\%$ |
| Depth (m) | $\leq \pm 0.3$ | $> \pm 0.3$ to 0.5 | $> \pm 0.5$ to 0.8 | $> \pm 0.8$ |
| %FS | Not applicable. | | | |

Preparation of the Review Package

Preparation of the review package will be completed annually by the project chief. The review package will contain the following items:

- Station description
- Station analysis
- Site visit check sheets (attachment 1)
- Calibration check sheets (attachment 2)
- Quarterly profile comparison field sheet (attachment 4)
- Primary computations table from ADAPS
- Annual field measurement summary form (to be created)
- Water quality variable shift correction tables from ADAPS
- Water quality datum correction value table from ADAPS
- Graphs of individual, uncorrected water quality parameters for review
- Graphs of individual, corrected water quality parameters for review

In order to efficiently manage the large amount of data collected at the water quality platforms, the project chief will update the review package within one week of each service visit. The review package will be checked and reviewed on a monthly basis by an experienced water quality technician and the district water quality specialist, respectively. The review package will be finalized at the end of the water year by the project chief. The final review package will be checked and reviewed by a qualified water quality technician and the district water quality specialist, respectively.

6.0 Attachments

Attachment 1-Lake Mead Water Quality Monitoring—Site Visit

Sheet (see next page)

Lake Mead Water Quality Monitoring—Site Visit Sheet

Site: _____ Date: _____ Weather: _____

Water: _____ Profiler: _____

Probes: _____ *Water Depth (meters):* _____

Air Temperature: _____ °C @ _____ Sounding: _____ Sonde ID Removed: _____

Barometric Pressure: _____ mmHg @ _____ Correction: +0.27 m Sonde ID Deployed: _____

Depth: _____ # of Samples Collected: _____

| Time | Depth (m) | Temp (°C) | pH | Specific Conductance (µs/cm) | Dissolved Oxygen (mg/L) | Dissolved Oxygen (%) | Turbidity (NTU) | %FS (unitless) | Sonde ID | Remarks |
|------|-----------|-----------|----|------------------------------|-------------------------|----------------------|-----------------|----------------|----------|---------------------|
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | Pre cleaned values |
| | | | | | | | | | | Pre cleaned values |
| | | | | | | | | | | Pre cleaned values |
| | | | | | | | | | | Post cleaned values |
| | | | | | | | | | | Post cleaned values |
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List Parameters Calibrated for Sonde: _____

Remarks: _____

Attachment 2- Multiprobe Calibration/Check Sheet (see the following two pages)

Multiprobe Calibration/Check Sheet 1 of 2

Instrument ID: _____ Date: _____

Calibration/check performed by: _____

Cole-Parmer turbidity meter (NTU) Criteria: $\pm 2\%$ of standard.

| Time | Reading | Standard | Remarks (include % difference) |
|------|---------|----------|--------------------------------|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

Dissolved Oxygen (mg/L) Criteria: $\pm .3$ mg/L

| Time | Reading (mg/L) | Reading (charge) | Temperature | Pressure | Calibration Value | Remarks (include difference) |
|------|----------------|------------------|-------------|----------|-------------------|------------------------------|
| | | | | | | |
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Chlorophyll ($\mu\text{g/L}$) No criteria established

| Time | Reading | Standard | Remarks |
|------|---------|----------|---------|
| | | | |
| | | | |
| | | | |
| | | | |

Turbidity (mg/L) Criteria: The greater of ± 2 NTU or $\pm 5\%$ of measured value.

| Time | Reading | Standard | Standard ID | Remarks (include difference) |
|------|---------|----------|-------------|------------------------------|
| | | | | |
| | | | | |
| | | | | |
| | | | | |

Multiprobe Calibration/Check Sheet 2 of 2

Instrument ID: _____ Date: _____

Calibration/check performed by: _____

Specific Conductance Criteria: The greater of $\pm 5 \mu\text{S}/\text{cm}$ or $\pm 5\%$ of measured value.

| Time | Reading | Standard | Lot #/Exp | Remarks (include difference) |
|------|---------|----------|-----------|------------------------------|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

pH (units) Criteria: ± 0.2 unit

| Time | Reading (pH unit) | Reading (mV) | Standard | Lot #/Exp | Remarks (include difference) |
|------|----------------------|-----------------|----------|-----------|---------------------------------|
| | | | | | |
| | | | | | |
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| | | | | | |

Temperature Criteria: $\pm 0.2 \text{ }^{\circ}\text{C}$

| Time | Reading | ASTM | Remarks |
|------|---------|------|---------|
| | | | |
| | | | |
| | | | |
| | | | |

Depth Criteria: For deep transducer (0-200 m), $\pm .3$ meter.

| Time | Reading | Depth | Remarks |
|------|---------|-------|---------|
| | | | |
| | | | |
| | | | |
| | | | |

Remarks: _____

Attachment 3: Chlorophyll Sample Sheet (see the next page)

Lake Mead Water Quality Platforms: Chlorophyll Sample Sheet

Station Identification: _____

Sample Date _____

1. Undiluted Grab Sample

Sample Time _____

Sample Volume _____

| Sensor Chlorophyll ($\mu\text{g/L}$) | Sensor percent fluorescence (%FS) | Comments |
|---|--------------------------------------|----------|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

2. 50 Percent Dilution Grab Sample

Sample Time _____

Sample Volume _____

| Sensor Chlorophyll ($\mu\text{g/L}$) | Sensor percent fluorescence (%FS) | Comments |
|---|--------------------------------------|----------|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

3. Blank Sample

Sample Time _____

Sample Volume _____

| Sensor Chlorophyll ($\mu\text{g/L}$) | Sensor percent fluorescence (%FS) | Comments |
|---|--------------------------------------|----------|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

Additional Comments _____

Attachment 4: Quarterly Profile Comparison Field Sheet (see the next page)

Quarterly Profile Comparison Field Sheet

Site Name: _____ Date: _____

Party: _____

Profile Begin Time _____ Profile End Time _____

Multiprobe 1 ID: _____

Multiprobe 2 ID: _____

Note: Both multiprobes should be serviced and calibrated prior to the simultaneous profile.

Multiprobe 1

| Depth (m) | Temp (°C) | pH | Specific Conductance (µS/cm) | Dissolved Oxygen (mg/L) | Turbidity (NTU) | %FS (unitless) |
|-----------|-----------|----|------------------------------|-------------------------|-----------------|----------------|
| | | | | | | |
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Multiprobe 2

| Depth (m) | Temp (°C) | pH | Specific Conductance (µS/cm) | Dissolved Oxygen (mg/L) | Turbidity (NTU) | %FS (unitless) |
|-----------|-----------|----|------------------------------|-------------------------|-----------------|----------------|
| | | | | | | |
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